

SIMULATION AND ANALYSIS OF ARTERIAL TRAFFIC OPERATIONS ALONG THE US 61 CORRIDOR IN BURLINGTON, IOWA FINAL REPORT

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ABSTRACT

Advancement in computer technology has made traffic simulation models more user-friendly. These models have become an integral part of traffic engineering allowing for the analysis of concepts prior to field implementation.

The Center for Transportation Research and Education (CTRE) used the traffic simulation model CORSIM to access proposed capacity and safety improvement strategies for the US 61 corridor through Burlington, Iowa. The comparison between the base and alternative models allow us to evaluate the traffic flow performance under the existing conditions as well as other design scenarios. The models also provide visualization of performance for interpretation by technical staff, public policy makers, and the public.

The objectives of this project are to evaluate the use of traffic simulation models for future use by the Iowa Department of Transportation (DOT) and to develop procedures for employing simulation modeling to conduct the analysis of alternative designs. This report presents both the findings of the US 61 evaluation and an overview of model development procedures.

The first part of the report includes the simulation modeling development procedures. The simulation analysis is illustrated through the Burlington US 61 corridor case study application. Part I is not intended to be a user manual but simply introductory guidelines for traffic simulation modeling. Part II of the report evaluates the proposed improvement concepts in a side by side comparison of the base and alternative models.

PART I

Traffic Simulation Modeling Development Procedures

INTRODUCTION

Computer simulation is a powerful technique for testing the impact of changes in system parameters where the effect of such changes cannot be determined analytically. It is also an appropriate tool for traffic experiments where similar field experiments are impractical. Simulation models are designed to duplicate the operation of an actual system over time. By simulating the functional characteristics of a system, these models are used to predict system performance for a variety of input scenarios.

Simulation models can be classified into generic tools and application-specific models. Traffic simulation models, which are tailored to only vehicular traffic on surface street and freeway networks, fall into the latter category. They provide information about the network that otherwise could not be determined without significant infrastructure or disruption of traffic flow.

There are a number of traffic simulation models, but none as widely validated and used as NETSIM. NETSIM represents traffic movements on local street networks. Its companion model, FRESIM, follows the same concept in modeling traffic operation on freeways. These models are available in an integrated simulation tool known as CORSIM. CORSIM was developed under FHWA sponsorship. It predicts operational performance of an integrated system consisting of local streets and freeways. The integration of the two models enables CORSIM to capture, for example, effects of a freeway ramp spill-over onto a local street and to measure delay on adjacent streets as a result of traffic re-routing due to a freeway incident.

The first part of the report describes the procedures for employing CORSIM to conduct the analysis of alternative designs along the case study US 61 corridor. It introduces the traffic simulation modeling to traffic engineers as an improved process for examining the changes in traffic operational performance as a result of improvements in traffic control or facility geometry.

PROBLEM STATEMENT

The US 61 corridor through Burlington, Iowa, is a four-lane divided roadway with nine signalized intersections (four fully actuated and five semi actuated), good access control, and a frontage road system. During the peak hours, the corridor operates under moderate traffic flow with no serious congestion. However, vehicles experience excessive delay at intersections due to lack of signal coordination. Permissive left turns during the high school's afternoon dismissal also create an unsafe situation on the corridor. Moreover, the proximity of frontage road intersections to the corridor's signalized intersections results in an overlap queues.

The Iowa Department of Transportation's (Iowa DOT) Engineering Division has requested an examination of strategies for improving the capacity and safety of the facility. Specifically, the Iowa DOT has asked that the following improvement strategies be considered as part of this examination:

- Signal optimization
- Signal coordination
- Right lanes additions at all intersections
- Restricted access control

SIMULATION MODELING PROCESS

The evaluation begins with the development of a base model. The model simulates traffic operations throughout the facility under current traffic conditions. It is recommended that the base model output be compared to the collected field traffic data to make sure that the model represents the existing conditions of the simulated traffic facility. An alternative model can then be built by modifying the base model and incorporating the desired improvement strategy. The following steps describe the general procedures to model traffic operations at the case study corridor:

1. Data Collection

The required data to generate the basic CORSIM input files are organized into three categories: supply, demand, and control. Supply data include geometric and traffic characteristics of the network. Number of lanes, lengths of turn bays of approaches to signalized intersections, and distances between intersections can be obtained from aerial photos. Additional field inspection may be required to determine lane widths, grade for each approach, and area type.

Demand data primarily include traffic counts at local streets and major arterials and turning movement counts at major intersections throughout the network within the study zone. These data can be obtained through automated traffic recorders and tube counts and/or can be collected manually using counter boards. Recent traffic and turning movement counts collected by local agencies are also useful. These data can be updated by factoring in the current traffic growth.

The control data consist of signal timing specifications at intersections. The control data can be obtained from local agencies and field observation. Information needed for signal controls include signal type (pre-timed, semi-actuated, fully actuated), phase plan, detector types and locations, and other applicable information.

2. Network Description

The next step in defining input data files for CORSIM is describing the geometry of the network. CORSIM uses the concept of links and nodes to define a traffic network. Links are streets or freeways, and nodes are usually the intersection of two or more links. The network should be laid out using the distances between intersections, number of lanes, and other data obtained from the field and local agencies.

3. Input File Development

CORSIM's input file consists of a sequence of "record types." Each record, also called a card, carries a specific set of data. These cards enable CORSIM to model the traffic operations of the case study network. The input file is a text file which can be edited with most available word processors.

The manual development of CORSIM's input file is a cumbersome job. ITRAF is an interactive computer program with a graphical interface developed to simplify and speed up the task of creating the input files. Because of its graphical interface, ITRAF eliminates the need to remember and understand "record types," thus greatly reducing the chances of making errors during manual input data entry process. Although, ITRAF carries a few internal bugs and it is no longer supported by the CORSIM's developer, it is a preferred method to manual development of text input files. ITRAF generates the CORSIM's input files. When identified, input errors can be corrected using text file format. ITRAF was included in the earlier version of CORSIM.

The latest version of Synchro (Synchro Professional 3.2) is the recommended software package for generating the CORSIM input file. Synchro is also a preprocessor for PASSER, TRANSYT 7F, and HCS software packages. Developed by Trafficware, Synchro is a complete software package for modeling and optimizing traffic signal timings.

3.1. Links and Nodes

A traffic network can easily be created in Synchro by adding street links. Intersections are created by crossing two links. Figure 1 shows a segment of the case study network which includes the main arterial and the adjacent frontage roads. The white circle indicates a signalized intersection whereas the black dots represent unsignalized intersections. Lane data, traffic volumes, and signal timings can be entered by clicking on an intersection.

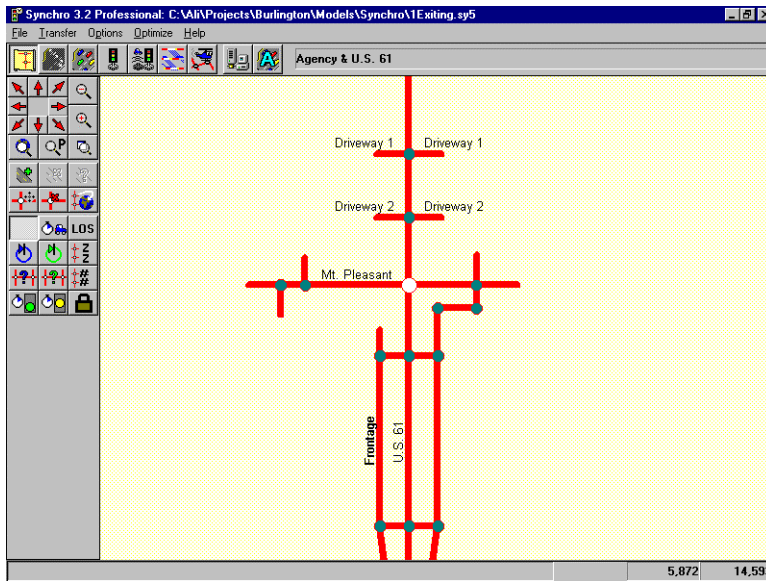


Figure 1. A Segment of the Case Study Network in Synchro

3.2. Lane Data

The lane data input window, shown in Figure 2, allows for input of lane group definitions, lane width, grade, area type, storage length, detector locations, and other applicable information. Lane group definitions affect how traffic is assigned between lane groups. Storage length data are used to determine potential blockage problems.

LANES	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Ideal Satd. Flow (vphpl)	12	12	12	12	12	12	12	12	12	12	12	12
Lane Width (ft)												
Grade (%)		0			0			0			0	
Area Type	Other			Other			Other			Other		
Storage Length (ft)	150		0	150		0	150		0	150		0
First Detector (ft)	50	50	50	50	50	50	50	50	50	50	50	50
Last Ext. Detector (ft)	0	0	0	0	0	0	0	0	0	0	0	0
Turning Speed (mph)	15		9	15		9	15		9	15		9
Right Turn on Red			Yes			Yes			Yes			Yes
Right Turn Factor (prot)	1.00	0.94		1.00	0.92		1.00	0.98		1.00	0.95	
Left Turn Factor (prot)	0.95	1.00		0.95	1.00		0.95	1.00		0.95	1.00	
Saturated Flow Rate (prot)	1719	3409		1719	3348		1719	3565		1719	3456	
Right Turn Factor (perm)	1.00	0.94		1.00	0.92		1.00	0.98		1.00	0.95	
Left Turn Factor (perm)	0.13	1.00		0.19	1.00		0.06	1.00		0.06	1.00	
Saturated Flow Rate (perm)	252	3409		349	3348		119	3565		119	3456	
Headway Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Saturated Flow Rate for permitted movements (vph)

Figure 2. Synchro Lane Data Input Window

3.3. Traffic Volumes

The volumes input window, shown in Figure 3, requires traffic volumes for each movement at an intersection, peak hour factor, growth factor, percent of heavy vehicles, and other related information. Synchro calculates the lane utilization factors and uses that along with the volumes, peak hour factor, and growth factor to calculate the adjusted flow for each movement.

VOLUMES	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Traffic Volume (vph)	204	274	197	147	223	112	154	545	139	140	485	150
Conflicting Peds. (#/hr)	0		0	0		0	0		0	0		0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Heavy Vehicles (%)		5			5			5			5	
Bus Blockages (B/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Adj. Parking Lane?	No	No	No	No	No	No	No	No	No	No	No	No
Parking Maneuvers (#/hr)												
Traffic from mid-block (%)		0			0			0				0
Adjusted Flow (vph)	227	304	219	163	248	124	171	606	154	156	539	167
Lane Utilization Factor	1.00	1.05	1.00	1.00	1.05	1.05	1.00	1.05	1.05	1.00	1.05	1.05
Lane Group Flow (vph)	227	319	219	163	390	0	171	798	0	156	741	0

Percentage of traffic from mid-block driveways (0% to 100%)

Figure 3. Synchro Traffic Volumes Input Window

3.4 Signal Timings

The timings window, shown in Figure 4, allows data input for signalized intersections. The input parameters include, left turn type, phase number, lead/lag assignment, minimum and maximum splits, and lost times (clearance and start-up). The assigned phase plan and splits are shown graphically by green and yellow bars at the bottom of the window. Splits can also be adjusted by holding down the computer mouse's left button and move it right or left. Synchro calculates the volume to capacity ratios for each lane group. Delays can be calculated according to either Webster or percentile delay methods. Level of service (LOS) for each lane group is then determined by the calculated stopped delay.

For unsignalized intersections, the only required input data are the movements allowed for each approach (stop, yield, or no control).

Synchro 3.2 Professional: C:\AI\Projects\Burlington\Models\Synchro\1\Exitng.syn

File Transfer Options Help

MT Pleasant & U.S. 61

Controller Type: Actuated-Uncoord

Current Cycle Length: 196

Natural C.L.: 70

Int. V/C Ratio: 0.57

Int. Delay: 16

Int. LOS: C

☐ Lock Timings

	EBL	EBT	EBR	WBL	WBT	NBL	NBT	SBL	SBT	PED
Left Turn Type	Perm+L			Perm+L		Perm+L		Perm+L		
Right Turn Treatment			Pm+Ov							
Phase Number	7	4		3	8	5	2	1	6	0
Phase Lagging?	Lead	Lag		Lead	Lag	Lead	Lag	Lead	Lag	
Phase can lead or lag?	Fixed	Fixed		Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	
Maximum Split (s)	34	64		34	64	34	64	34	64	
Minimum Split (s)	14	19		14	19	14	19	14	19	
Yellow + All Red Time (s)	4	4		4	4	4	4	4	4	
Lost Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0	3.0	
Green to Cycle Ratio	0.48	0.31	0.47	0.48	0.31	0.48	0.31	0.48	0.31	
Actuated G/C Ratio	0.41	0.26	0.38	0.35	0.24	0.47	0.32	0.43	0.31	
Volume to Capacity Ratio	0.50	0.28	0.30	0.33	0.36	0.53	0.73	0.50	0.68	
Actuated V/C Ratio	0.59	0.34	0.37	0.47	0.48	0.66	0.72	0.65	0.68	
Percentile Delay (s)	11.2	17.1	10.1	11.0	19.6	12.0	16.7	13.4	16.7	
Level of Service	B	C	B	B	C	B	C	B	C	

Level of Service for Lane Group (A to F)

V/C ok Mins ok

Figure 4. Synchro Traffic Volumes Input Window

3.5. Actuated Settings

The actuated settings window, shown in Figure 5, indicates the input data needed for all actuated intersections. These data include minimum green time (same as maximum split minus yellow time), vehicle extension, recall mode, and other related information. Synchro models actuated signals under different traffic scenarios using percentile delay method. In this method, traffic volumes for each approach are adjusted up or down to model each scenario.

	7 EBL	4 EBT	3 WBL	8 WBT	5 NBL	2 NBT	1 SBL	6 SBT
Minimum Initial (s)	5	10	5	10	5	10	5	10
Maximum Green (s)	30	60	30	60	30	60	30	60
Vehicle Extension (s)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Minimum Gap (s)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Time Before Reduce (s)	0	0	0	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0	0	0	0
Recall Mode	None	None	None	None	None	None	None	None
Pedestrian Phase	No	No	No	No	No	No	No	No
Walk Time (s)								
Flash Dont Walk (s)								
Pedestrian Calls (#/hr)								
90th %ile Green Time (s)	19 gp	27 gp	14 gp	22 hd	17 gp	35 gp	17 gp	34 hd
70th %ile Green Time (s)	12 gp	17 gp	10 gp	15 hd	11 gp	23 gp	11 gp	23 hd
50th %ile Green Time (s)	9 gp	12 gp	7 gp	10 hd	8 gp	17 gp	8 gp	17 hd
30th %ile Green Time (s)	7 gp	11 hd	6 gp	10 mn	6 gp	13 gp	6 gp	13 hd
10th %ile Green Time (s)	0 sk	10 mn	0 sk	10 mn	0 sk	10 mn	0 sk	10 mn

Figure 5. Synchro Actuated Signal Input Window

4. Input File Generation

The data entry for generating the CORSIM input file of the base simulation model is completed at this point. Choose Transfer from the Synchro's toolbar. The selection of CORSIM Analysis on the pull down menu opens up the Perform CORSIM Analysis dialog box shown in Figure 6. Enter the location of the CORSIM program (normally c:\tsis4\tsis.exe) in the TSIS Program Location box. Enter the path of the CORSIM input file in the Data Filename box. By default, Synchro generates an input file for CORSIM in the current path and under the same file name. Click on the Make TRF File button and a CORSIM input file is generated in the designated directory.

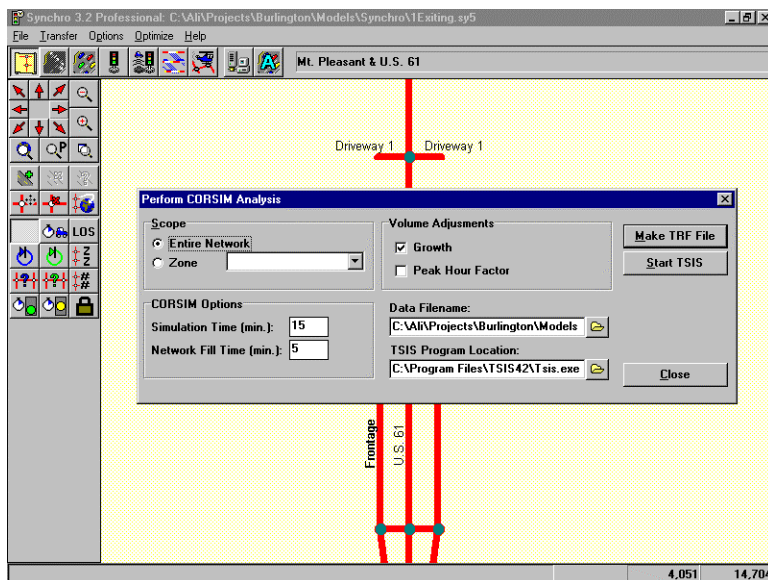


Figure 6. CORSIM's Input File Generation Dialog Box in Synchro

5. CORSIM

Start CORSIM by executing the *tsis.exe* file. Create a project in the directory with the generated CORSIM input file. Figure 7 shows the screen after the project is opened. Click on the generated input file (the file with a *trf* extension) and click on the CORSIM icon (the one with FHWA logo). This process generates a lengthy output file (the file with an *out* extension) which can be viewed by double clicking on the file. It also creates an animation file which can be viewed in TRAFVU. Highlight the input file and click on the TRAFVU icon located on the toolbar to view the animation file.

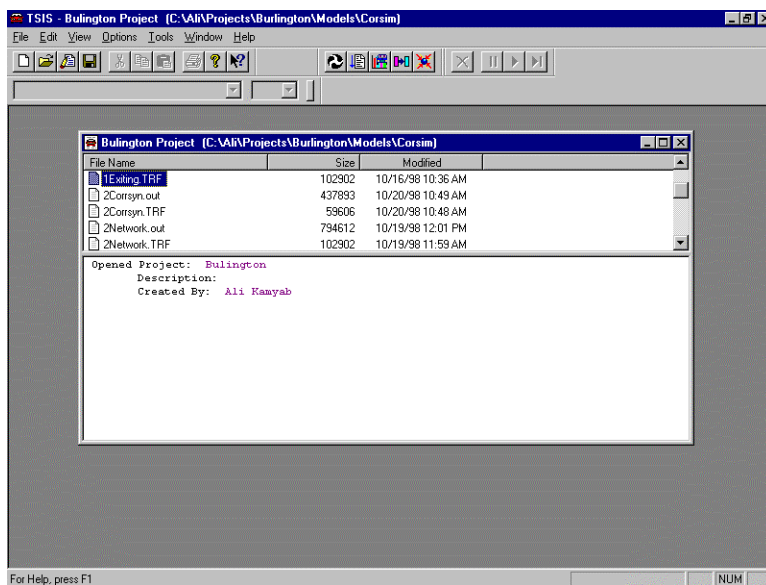


Figure 7. CORSIM Project Window

TRAFVU is an interactive graphics processor designed to display and animate the results of CORSIM models. TRAFVU allows for a side by side visual comparison. TRAFVU is suitable for traffic operations analysis as well as the presentation of before-and-after studies to convince the audience of the utility of simulation results. Figure 8 presents a TRAFVU display of a section of the simulated case study network.

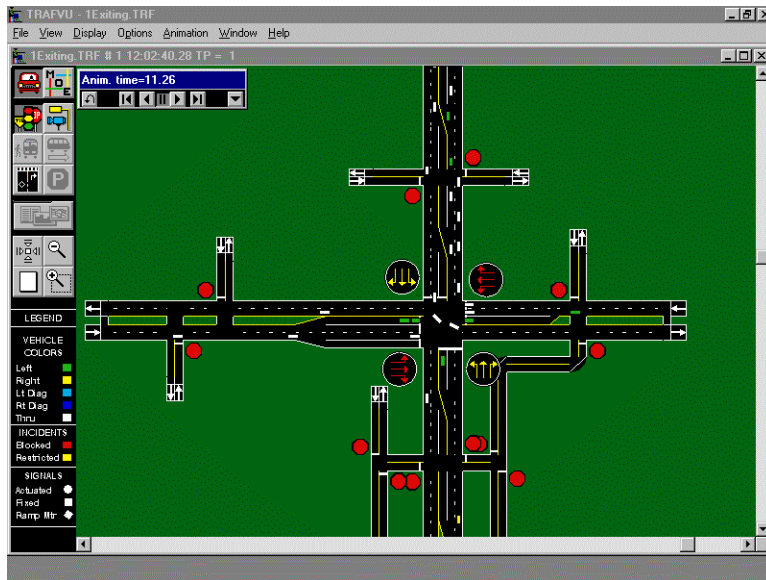


Figure 8. Animated Case Study Network in TRAFVU

6. Alternative Models Development

Once a base model is developed, it can be modified to model the proposed improvement strategies. The proposed improvement strategies such as optimizing signal timings or adding right lanes can be implemented in the base model by optimizing the case study network or adding exclusive right lanes at designated intersections in the Synchro environment. Follow the procedures described in steps 4 and 5 to create the alternative models. The effectiveness of the implemented strategies in reducing traffic delay and other applicable measures of effectiveness (MOE) can be evaluated by comparing results of the base and alternative models.

Both Synchro and CORSIM provide several MOEs, including delay, emission, and fuel consumption. Synchro is a macroscopic model whereas CORSIM is a microscopic model. Traffic flow modeling in macroscopic models are based on fundamental flow-density-speed relationships. Microscopic models, on the other hand, consider individual vehicle interactions to model traffic flows. The car-following and lane-changing algorithms have made microscopic models more reliable in calculating delay in traffic spill-over and blocking conditions. However, both models would be appropriate for comparing different alternatives in relative terms.

CONCLUDING REMARKS

The simulation model may provide results which are not identical to the observed system. The purpose of model validation is to determine if the model replicates the actual system at an acceptable level of confidence. It is a good practice to compare simulation results to the real system to validate the obtained results. The comparison of the field data with the model's outputs establishes a level of confidence that the model is capable of simulating the existing conditions at the case study traffic facility.

The purpose of this document is to introduce traffic engineers to an improved process for examining the changes in traffic operational performance. Both Synchro and CORSIM provide comprehensive users' manuals which explain traffic network modeling procedures in detail.

PART II

Improvement Strategies Evaluation of US 61 Corridor

INTRODUCTION

The Iowa DOT's Engineering Division has requested that CTRE use the US 61 corridor in Burlington, Iowa, as an example of the use of traffic simulation methods. Using the corridor as a case study, concepts believed to increase capacity and improve safety were examined through the use of simulation. CTRE developed several simulation models of the traffic network using CORSIM. These models represent traffic operations at the facility under the existing conditions as well as proposed improvement strategies. This part of the report describes each model and presents the obtained results.

BASE MODEL

The base model represents the current traffic operations for the US 61 corridor in Burlington. It was developed by following the procedures described in the first part of this report. US 61 is a north-south corridor through the City of Burlington, Iowa, which connects nine signalized intersections. There are a number of unsignalized intersections throughout the case study network which have been included in the model. Table 1 includes the traffic control type for each intersection along the corridor.

Table 1. Controller Types Along the Burlington US 61 Corridor

Intersecting Street	Control Type
Sunnyside Avenue	Actuated
Mt. Pleasant Avenue	Actuated
Kirkwood Avenue	Semi-Actuated
U.S. 34 Westbound On/Off Ramp	Semi-Actuated
U.S. 34 Eastbound Off Ramp	Semi-Actuated
Agency Street	Actuated
Market Street	Semi-Actuated
Division	Semi-Actuated
West Avenue	Actuated

Traffic Data Collection

Traffic volumes were collected manually and using a video imaging system. In this study, traffic volumes were collected over a period of three days during the morning peak (7-9 AM), noon peak (12-2 PM), and the afternoon peak (4-6 PM). Traffic volumes and turning movements were recorded at each intersection along the network during at least one peak period. Because data were not collected at all locations at the same time, the data collected may not exactly represent the actual volumes at any single time for the entire network. For example, data collected at 8:00 AM Friday for the intersection of US 61 and West Avenue showed 637 vehicles per hour travelling north from the intersection of West Avenue to the intersection of Johannsen Avenue.

Data for the US 61 and Johannsen Avenue intersection, however, were collected at 8:00 AM the preceding Thursday and only showed 401 vehicles travelling into the intersection from West Avenue.

To balance volumes throughout the network, the US 61 and Agency Avenue intersection was selected as the reference intersection. Data recorded at this intersection on Thursday, July 16, 1998 from 4:00 to 5:00 PM indicates the highest observed traffic volumes along the corridor. Traffic volumes at all other intersections were adjusted accordingly using the available turning movement percentages throughout the network. Table 2 presents the adjusted volumes for all intersections throughout the network on the Thursday afternoon peak period. The highlighted records in Table 2 are the signalized intersections.

Table 2. Collected Traffic Volumes Throughout the Network

[illegible]

Because the number of intersections that could be observed at one time with the video detection equipment was limited by the number of systems available, data were collected at inconsistent periods of the day resulting in the potential for errors. Simulation modeling of a network requires area wide data collection conducted simultaneously. Tube counts would have been a better choice for data collection to support traffic simulation modeling at the network level. In this study, all traffic volumes were increased by 15 percent to emulate the observed queue backup and congestion.

ALTERNATIVE MODELS

Once the base model was built, five other models representing alternative solutions were built by modifying the base model. The last three alternative models were optimized and coordinated in addition to other implemented improvements.

Network Optimization

The splits and cycle lengths of all signalized intersections throughout the case study network were optimized under the existing conditions using Synchro. Synchro minimizes stops and delays which is similar to the TRANSYT 7F's signal timing technique.

Signal Coordination

The five semi-actuated controllers were changed to full-actuated controllers along the case study corridor. All nine full-actuated intersections were coordinated by optimizing the corridor cycle lengths and offsets using Synchro.

Right Turn Bay Additions

Right turn bays were added at designated intersections. These bays were added at intersections with high volumes of right turning traffic to alleviate congestion in the through lanes. The bays were assumed to be 150 feet long and 12 feet wide. The signals along the corridor were optimized and coordinated.

Access Control Modification

This alternative model includes the proposed modification to the existing access control along the corridor. The signals along the corridor were also optimized and coordinated. There were eight areas of modification which are presented in Table 3.

Table 3. Access Modifications on the Burlington US 61 Corridor

Intersecting Street	Modification
Frontage road access south of Sunnyside	<ul style="list-style-type: none"> • No left turns from eastbound or westbound approaches • Extend frontage road east of US 61 north to Sunnyside
Second driveway access north of Mt. Pleasant	<ul style="list-style-type: none"> • No left turns from westbound approach • No left turns from southbound approach
First frontage road access south of Mt. Pleasant	<ul style="list-style-type: none"> • Extend west frontage road north to Mt. Pleasant past Days Inn • No left turns from eastbound or westbound approaches
Second frontage road access south of Mt. Pleasant	<ul style="list-style-type: none"> • No left turns from eastbound or westbound approaches
Kirkwood Avenue	<ul style="list-style-type: none"> • Frontage road west of US 61 pushed back 90 feet to a distance of 185 feet from intersection of US 61 and Kirkwood
Market Street	<ul style="list-style-type: none"> • Frontage road west of US 61 pushed back 80 feet to a distance of 171 feet from intersection of US 61 and Market
Division	<ul style="list-style-type: none"> • Frontage road west of US 61 pushed back 80 feet to a distance of 171 feet from intersection of US 61 and Division
Johannsen	<ul style="list-style-type: none"> • No left turns from eastbound or westbound approaches

Combined Improvements

The last alternative model includes all proposed improvement strategies (i.e., right and left lane additions, access control modification, signal coordination). The signals along the corridor were optimized and coordinated.

RESULTS

The effectiveness of the proposed improvement strategies is evaluated by comparing the five alternative models to the base model. The models are compared in terms of intersection levels of service (LOS), signal delays, and average traveling speeds.

Figure 9 compares the resulting intersection levels of service of the six models. LOS 1 is equivalent to LOS A, which represents unimpeded traffic movement or free flow. LOS 5 is equivalent to LOS F, which represents heavy congestion and/or gridlock. The levels of service at West, Division, Ramps, and Sunnyside intersections do not indicate any changes when comparing each alternative to the base model because they currently operate under normal conditions (LOS B). There are, however, improvements in levels of service at the Market, Agency, Kirkwood, and Mt. Pleasant intersections. The base model indicates the levels of service F at Agency and Kirkwood intersections. These intersections will benefit the most by right lane additions throughout the network.

As shown in Figure 9, the access modifications improve the levels of service but not as significantly as adding the right turn lanes. Adding right lanes at the intersections has direct impact on reducing signal delays which are the key factors for the LOS determinations. Accesses, on the other hand, were modified mainly at driveways and unsignalized intersections along the corridor which would have impact on improving safety and delay at these access points.

Moreover, combining all improvement strategies does not improve the levels of service as much as adding right turn lanes. Adding right lanes provides better overall levels of service than combining all improvement strategies. This is an indication that perhaps the selected accesses are not the best locations in need of treatments. Other access control strategies could prove to be more effective in improving levels of service at the intersections.

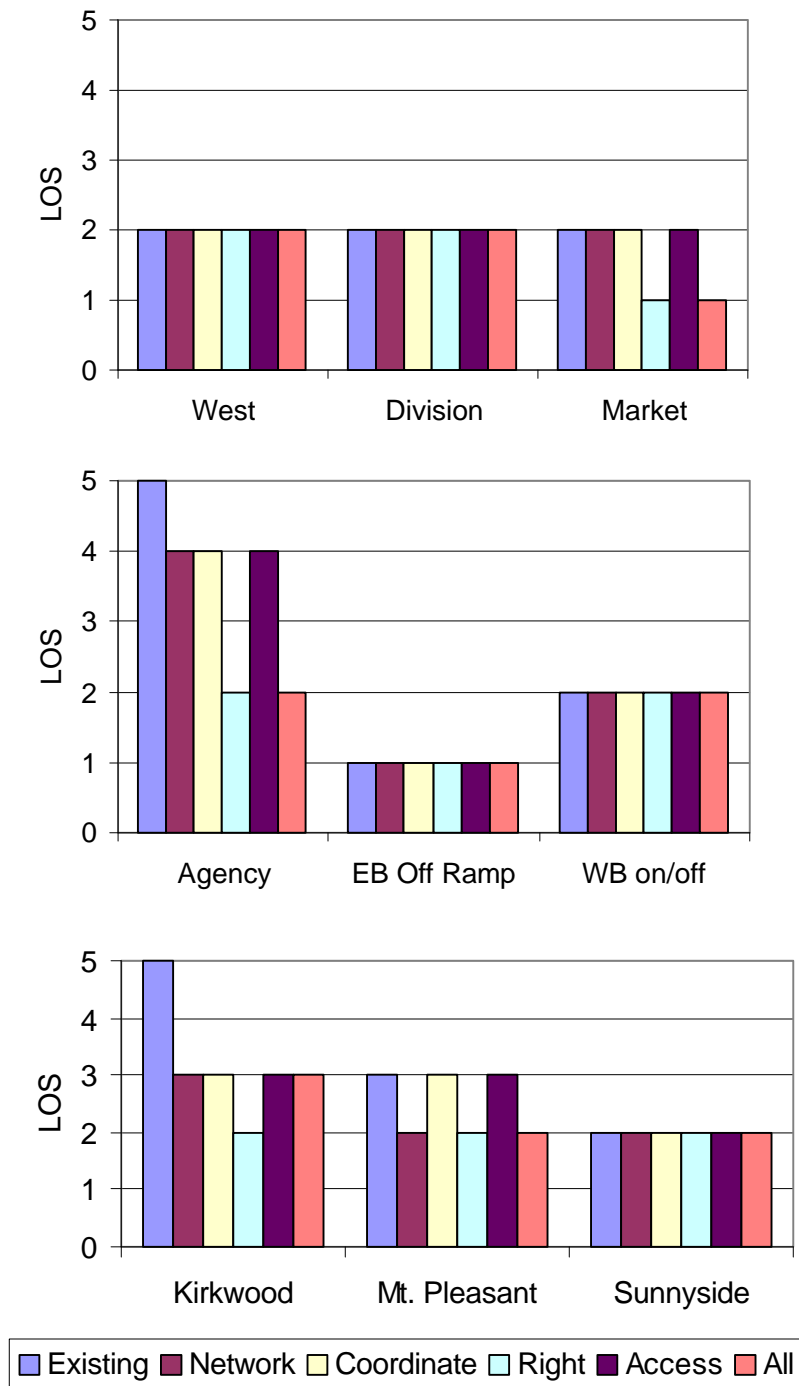


Figure 9. Network Level of Service Comparison

Figure 10 compares the network total signal delay and average speed resulting from the base and alternative models. As signal delay decreases, the average speed increases. It is again apparent that adding the right turn bays decreases the signal delay and increases average speed more significantly than the other alternatives.

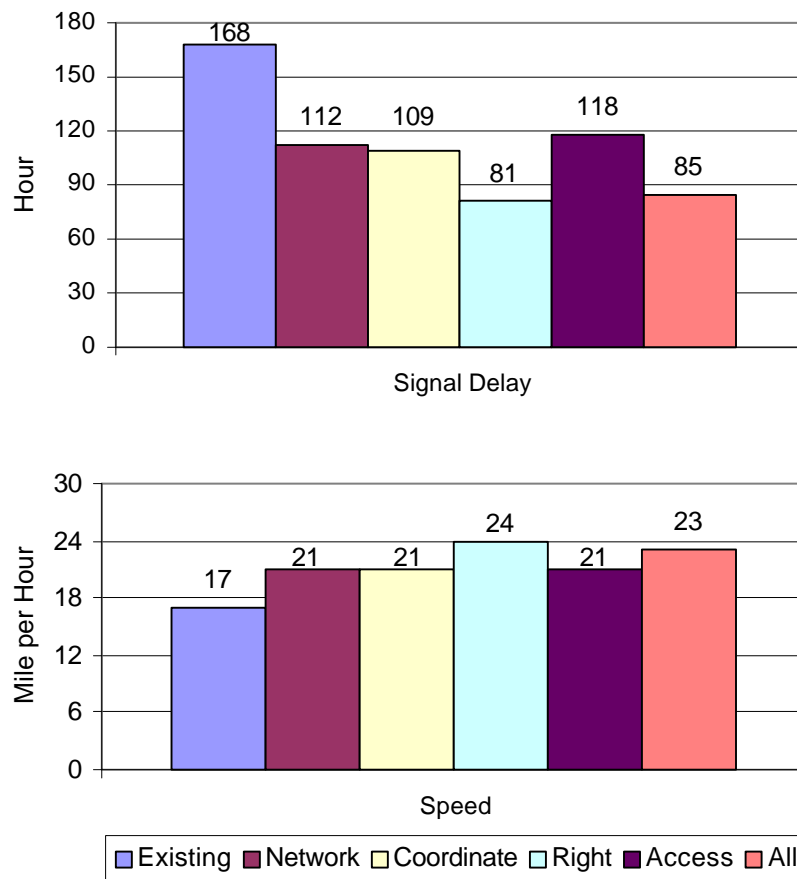


Figure 10. Network Total Signal Delay and Average Speed Comparison

In order to evaluate the effectiveness of signal coordination in reducing delay and improving speed along the corridor, the frontage road system and adjacent intersections on minor streets were eliminated from the base model. Figure 11 compares the levels of service along the corridor between the corridor's base and coordinated models. This Figure shows that signal coordination improves levels of service at the Agency and Kirkwood intersections. The Agency intersection carries the highest traffic volume among the intersections on the corridor. Figure 12 compares the corridor total signal delay and average speed. It is apparent that coordinating signals decreases total signal delay and increases average speed.

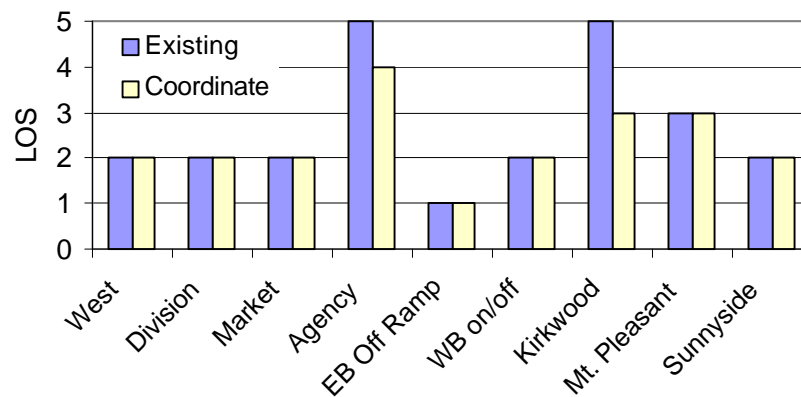


Figure 11. Corridor Level of Service Comparison

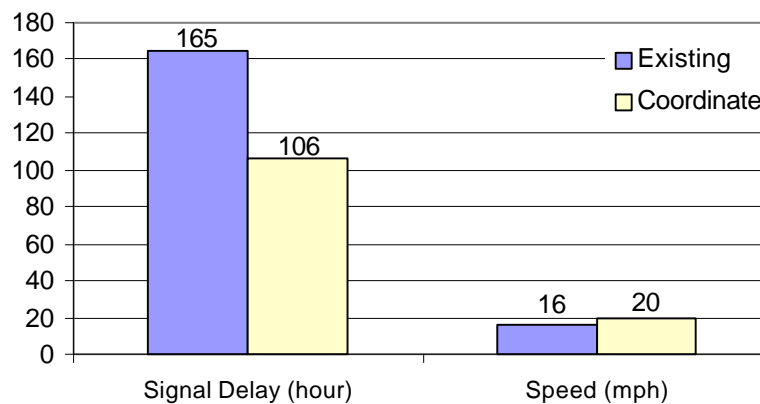


Figure 12. Corridor Total Signal Delay and Average Speed Comparison

CONCLUDING REMARKS

Among the proposed improvement strategies, the right lane additions model indicates the most significant improvement in reducing delay throughout the network. Network signal optimization and coordination models both prove to be beneficial at enhancing traffic flow operations throughout the network. Because of the cost and time involved with adding right lanes and modifying access control, optimizing and coordinating the signals could serve as an interim solution before conducting other improvement strategies.

The alternative models included in this report indicate only a sample of feasible improvement strategies. There are many other improvement strategies which could be examined in different

models. For example, new models can be built for different access control, signal control, and signal coordination strategies. Coordinatability factors (CF), provided by Synchro, is helpful in the modeling of different signal coordination strategies. Intersections with high CFs are recommended for signal coordination. It may be more cost effective to coordinate only the best candidate intersections. The Coordinatability factors measure the desirability of coordinating the intersections in Synchro. Travel time between intersections is the most important element in determination of the CFs.

TRAFVU, the animation component of CORSIM, is another excellent source for detecting problem locations throughout the network. Left lane blockage by through lanes, malfunctioning signals, queue spill-over conditions, and other problems can easily be detected by watching traffic movements throughout the network in TRAFVU. Solutions for these type of problems include the modification of signal timings and/or the extension of left turn lanes.